VIII

THE METAGALAXY

TWO systematic surveys of external galaxies, now in progress at Harvard, concern the all-embracing aggregate which we call the metagalactic system. Most of the external systems seem to be scattered more or less at random, both in direction and in distance, except that in low galactic latitudes they are rarely found, presumably because of obstructions by obscuring nebulosities in and on the edges of the Milky Way. A relatively small percentage of the total number of recorded spiral and spheroidal nebulae are assembled into the distinctly delineated supergalaxies.

The less ambitious of the two surveys is a catalogue of the photographic magnitudes of all external galaxies brighter than magnitude 12.9. In the existing general catalogues, such as the N. G. C. and Index lists of Dreyer, the estimated total magnitudes of the nebulae and clusters are only approximate, being referred to uncertain visual standards. Some lists, with higher accuracy in the magnitudes, cover but limited sections of the sky. It is hoped that the new Harvard survey will be more complete and homogeneous than any so far made. Numerous photographs showing the nebulae on a sufficiently small scale for comparison with standard star images are available for the whole sky. Three or more photographs are used for each object. Positions will not be redetermined (they are available from existing catalogues), nor the dimensions measured. The work is simply a photographic magnitude survey. At the time of

writing seventy per cent of the whole sky has been covered, and Miss Ames has measured 675 galaxies brighter than magnitude 12.9. We may assume that this examination of the nearer parts of the Metagalaxy is reaching some five million light years into space, though doubtless many of the intrinsically fainter galaxies within that limit of distance are not recorded, and many of the high luminosity galaxies appear in the catalogue though lying considerably more than five million light years distant.

The second systematic survey in the Metagalaxy reaches to the eighteenth magnitude and fainter and is much more complicated and laborious than the photometric catalogue of objects to magnitude 12.9. The first survey will be completed in a few months, but we shall be fortunate if the second is finished in ten years. It will involve the finding and study of tens of thousands of heretofore uncatalogued objects. The positions, approximate magnitudes, diameters, and classifications of all these faint systems must be completed before the final analysis is made. We may assume as a first approximation that this survey, using long-exposure Bruce photographs which extend to objects five magnitudes and more fainter than those in the catalogue of the nearer systems, will reach to an average distance of fifty million light years. As in the first survey, the limit is indefinite, more distant objects coming in if they are of high luminosity and nearer objects failing to appear if intrinsically faint.

An independent survey of the distribution in brightness and direction of faint galaxies is being made with the Mount Wilson reflectors by Dr. Hubble. The areas covered by him are much smaller than those shown on the Harvard plates, but the magnitude limits are fainter and the total number of nebulae involved is at present of the same order. Hubble's survey is mainly for the northern hemisphere and

the Harvard survey mainly for the southern. These supplementary researches give results in general accordance.

The Harvard eighteenth magnitude survey, as we may call it, has now progressed to the extent shown in Figure 23, which is a map of the whole sky with the completed areas shaded. Each long-exposure Bruce plate covers effectively twenty five square degrees. Approximately one sixth of the whole sky has been examined. About eighteen thousand new systems have been found, for seventy five per cent of which the positions have been determined and for fifty eight per cent classifications made on the Harvard system. In this work low quality photographs have been excluded. The limit to which the satisfactory plates extend is variable, depending on sky conditions and plate sensitivity. Through counts of stars on each photograph we shall be able to determine the approximate limits to which the nebulae are shown.

The number of galaxies per square degree has been counted on all plates in the shaded areas shown in Figure 23, and in Figure 24 the results of this census are given with angular distances from the galactic plane (galactic latitudes) as abscissae and the number of galaxies per square degree as ordinates. Each plotted point refers to a single plate. In low galactic latitudes, though the plates are numerous and of good quality, relatively few galaxies are shown, but for galactic latitudes greater than plus or minus thirty degrees the numbers per square degree average about 14.6 and show great dispersion. We must conclude that the distribution is far from uniform.

The magnitudes of individual galaxies have been estimated for a few fields in the eighteenth magnitude survey and Figure 25 shows the frequency curve for four sample regions. The dissimilarities in these curves are an indication of the

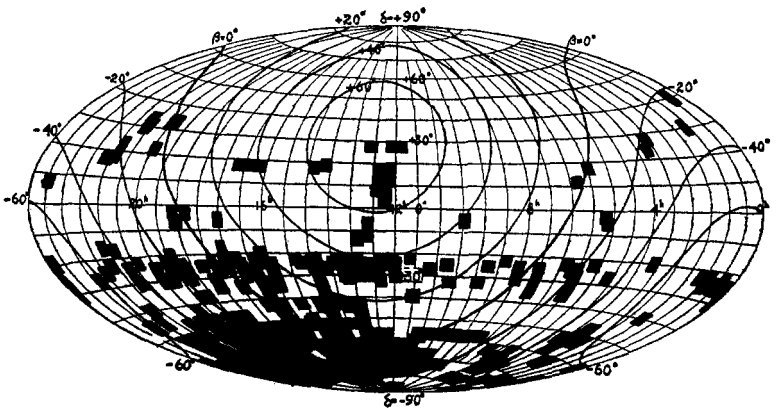

FIGURE 23. Regions of the sky covered by the survey of faint external galaxies. The heavy curved line is the galactic circle. The map is given in the equatorial system of coördinates, but shows also galactic latitude circles.

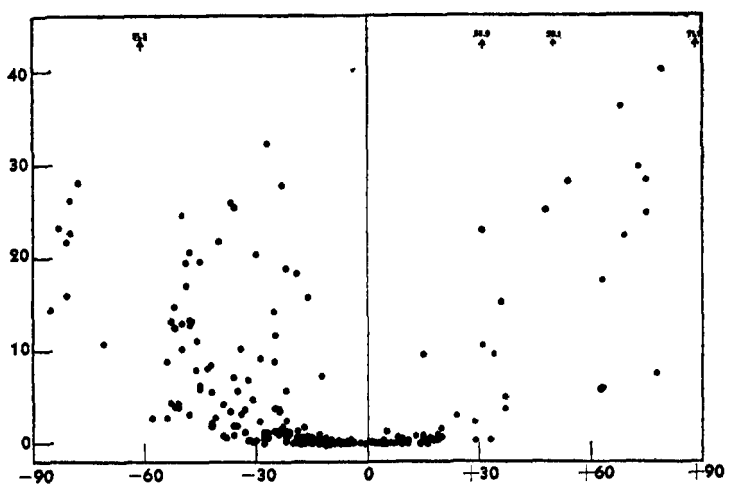

FIGURE 24. Frequency of external galaxies. Ordinates are numbers of galaxies per square degree; abscissae are galactic latitudes.

non-uniform increase in number of galaxies with increasing distance. If the density in space were uniform the number of objects per square degree should increase four times for

every interval of one magnitude (abscissae). Taking the whole sky, we find, in agreement with Hubble, that the increase of numbers with decreasing brightness is approximately of the order of magnitude appropriate to uniform density. But for various large sections of the sky the uniformity criterion fails conspicuously, as shown in Figure 25; for some of the fields, apparently free of supersystems, the number of

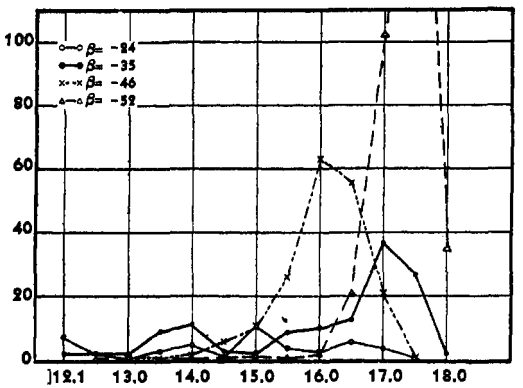

FIGURE 25. Magnitude frequency of external galaxies for four regions. Coördinates are numbers of galaxies and photographic magnitudes.

objects actually falls off with decreasing brightness and for others increases and decreases irregularly.

The current theoretical discussions of the dimensions and finiteness of the space-time world assume a general uniformity in the distribution of galaxies throughout measurable space; hence the interest in extending the census of faint galaxies, and in the measurement of their magnitudes and angular diameters to the faintest possible limits.

In conclusion, two results of our survey of the Metagalaxy merit emphasis. The first is that within the range of existing telescopes we find great irregularity in the distribution

of matter. Some of this irregularity is apparent only, caused by obscuring cosmic clouds in the neighborhood of the Milky Way; but much of it is attributable to the aggregations of galaxies into supersystems and into large indefinite streams.

The second result to be emphasized is that the survey gives no evidence that we have measurably approached the limits of the galaxy-populated universe; on the whole we have no indication that the systems are falling off in number per cubic million light years as we go out from the Sun. On relativistic grounds, the red shift in the spectra of distant galaxies can be taken as an observational indication of an expanding finite universe; but so far as the present census of the Metagalaxy goes, the total number of galaxies and the radius of space may both be infinite.

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